FIR:AQ/Conf/76/E.22

CONTENTS

A MODEL CLOSED SYSTEM FOR AQUACULTURE, INCORPORATING THE RECYCLING OF WASTES

Abstract

Much aquacultural research is conducted without the use of appropriate model systems. Models of aquaculture systems can be valuable aids in measuring the value of supplemental inputs planned to increase production per unit of area. The complex interactions occurring among the many factors influencing production are particularly difficult to evaluate without adequate control. An intensively regulated model can be used to obtain necessary control.

An example of a model closed system is discussed and observations are made regarding those inputs to the system which have been most valuable for the high-density culture of penaeid shrimp.

It is hoped that this paper will encourage: (i) the use of models to explore the benefits of environmental control in aquaculture; (ii) definition of various inputs and environmental parameters by researchers so that results can be used by others; and (iii) investigation of innovative and sophisticated approaches to environmental control for aquaculture.

UN MODELE D'AQUICULTURE EN SYSTEME CLOS INCORPORANT LE RECYCLAGE DES EFFLUENTS

Résumé

Une bonne partie des recherches aquicoles est effectuée sans recours à des modèles de systèmes appropriés. Les modèles de systèmes aquicoles peuvent constituer d'utiles auxiliaires pour mesurer la valeur des inputs supplémentaires auxquels il est prévu de recourir pour accroître la production par unité de surface. Les interactions complexes qui interviennent entre les nombreux facteurs dont dépend la production sont particulièrement difficiles à évaluer sans témoin adéquat. L'on peut utiliser un modèle rigoureusement contrôlé pour obtenir le témoin nécessaire.

L'auteur examine un modèle de système clos, et communique des observations concernant les inputs ajoutés au système qui se sont révélés les plus utiles pour l'élevage en forte densité de crevettes pénéides.

L'on espère que ce document encouragera: (i) l'emploi de modèles pour étudier les avantages du contrôle de l'environnement dans l'aquiculture; (ii) la définition de divers inputs et paramètres écologiques par les chercheurs de manière que leurs résultats soient utilisables par d'autres; et (iii) l'étude de méthodes novatrices et modernes applicables au contrôle de l'environnement dans l'aquiculture.

MODELO DE SISTEMA CERRADO PARA ACUICULTURA, CON RECICLAJE DE DESECHOS

Extracto

Son muchas las investigaciones acuícolas que se realizan sin emplear modelos adecuados. Los modelos de sistemas de explotación acuícola pueden constituir una ayuda valiosa para mensurar el valor de los insumos suplementarios que tienen por objeto aumentar la producción por unidad de superficie. Especialmente difícil es evaluar, sin un control adecuado, las complejas interacciones que se producen entre los muchos factores que influyen en la producción. Para lograr el control necesario puede utilizarse un modelo regulado intensivamente.

Se examina un ejemplo de modelo de sistema cerrado y se hacen algunas observaciones sobre los insumos aportados al sistema que se han demostrado más útiles para el cultivo de camarones peneidos en grandes densidades.

Se espera que este documento fomente: (i) el empleo de modelos para explorar los beneficios del control del medio ambiente en la acuicultura; (ii) la definición de los diversos insumos y de los parámetros ambientales por parte de los investigadores, de modo que sus resultados puedan ser aprovechados por otros; y (iii) el estudio de enfoques innovadores y perfeccionados del problema del control del medio ambiente para la explotación acuícola.

1. INTRODUCTION

In most aquacultural activities some of the costs are related to their space requirements. Consequently, a significant proportion of aquacultural research and development is aimed at increasing the production per unit of area. In fact, a commonly used measure of success in aquaculture is a statement of the production per unit area.

Unfortunately, much of the research directed toward refinement of culture systems to improve production has been trial-and-error testing of various inputs under poorly controlled conditions. There has been a notable absence of functional models in which parameters can be controlled and supplemental inputs evaluated effectively. The typical outdoor pond is not entirely satisfactory as a model because factors influencing production (e.g., weather, disease, predation, competition and the general ecology of the pond) frequently cannot be controlled. The effects of uncontrolled variables which may be interacting with the experimental variables complicate the interpretation of results, sometimes to an extent that actual relationships between the organism and its environment cannot be determined.

In addition to the value of model systems in evaluating inputs and understanding the complex interactions among various inputs, models are useful in providing a framework for conceptualizing a system and planning experimentation. An intensively regulated model can provide many clues to the correct management of less intensively managed systems. The increased use of model aquaculture systems in teaching and demonstration situations should also be considered.

2. CHARACTERISTICS OF A MODEL AQUACULTURE SYSTEM

Since man has had more experience with terrestrial animals than with aquatic animals, it is logical for him to look at the most successful terrestrial animal husbandry systems to predict the kinds of controls which will be economical in aquaculture. The chicken industry has developed highly controlled systems with consequent production of a low-priced product. Many of the controls successfully and economically exercised in the chicken industry are usually not exercised by aquaculturists. Some examples of these are: elimination of predation; effective treatment of disease; breeding of genetically superior strains; and complete control of food intake.

Functional experimental models should be designed so that measurements can be made of the effects of varying levels of inputs of several types. The interactions or synergistic effects of these inputs may also occur and need to be understood. Although any single model may not be adequate to evaluate the effects of all inputs, a classification of inputs is listed below as a guide to the design of suitable models.

(a) Stocking
- (i) Density
- (ii) Variety and strain
- (iii) Species combinations

(b) Feeding
- (i) Presentation of prepared feed
  - Type
  - Amount
- (ii) Growth of natural foods
- (iii) Fertilization to promote plant and animal growth

(c) Aeration

(d) Water Circulation

(e) Temperature Control

(f) Chemical Control

(i) Pesticides
(ii) Herbicides
(iii) Disease treatment

(g) Labour Requirements

(h) Waste Removal

(i) Water exchange
(ii) Ecological recycling
(iii) Filtration

Although not complete, this list of inputs serves to demonstrate the types of controls a researcher may wish to evaluate as well as the complexity of interactions which may occur. The researcher's ability to control parameters in a model system distinguishes the model from other systems in which the scientist can only monitor changes. As one learns to control research systems, a degree of standardization will be possible and research results from one location will have comparative value in other situations.

As the ability to measure and control these inputs improves in a model, so the ability to evaluate individual inputs is greatly enhanced. Because the costs of the various inputs vary greatly among geographical locations, the capability of measuring the value of these inputs in each location is needed.

3. EXAMPLE OF A MODEL CLOSED SYSTEM

Because of the expense of land and labour in the United States, efforts have been made at the Gulf Coastal Fisheries Center in Galveston, Texas, to evaluate a carefully controlled closed raceway system. Initial models of the system were described by Mock, Neal and Salser (1974).

The system has evolved as techniques for the control of environmental conditions and waste removal have been improved. In most cases existing water treatment technology has been modified only slightly for the special applications of marine aquaculture (Mock, Ross and Salser, MS; Mahler, Groh and Hodges, 1975). The most recent model (Mock and Neal, MS) is a portable tank lined with plastic with a floating centre wall which supports airlift pumps. The detailed techniques will not be discussed in this paper since this information is reported in Mock and Neal (MS); the approaches taken and the principles incorporated into this model to date are outlined below.

A high level of control over the stock in this model is possible because the tank is completely drained between experiments and water is filtered when the system is filled. The fact that the system is closed and plastic tank covers are used virtually eliminates predators and competitors.

A formulated pellet ration is fed at predetermined rates to shrimp in this system. The rations (Zein-Eldin and Fenucci, in preparation) have been shown to produce good growth in penaeid shrimp for extended periods. Although algae and small invertebrates grow in the system, the artificial feed is the primary source of food for the shrimp. Efforts to control the ecology of the tanks are discussed in the section describing waste removal. Stability of the pellets has been a problem because of continuous water movement and associated rapid disintegration of the feed; however, this problem was corrected through the use of an alginate binder. Decomposition of feed and shrimp wastes are uncontrolled sources of fertilization; however, no other fertilizers were used.

The aeration system used is an airlift pump system described by Mock, Neal and Salser (1974) and Mock, Ross and Salser (MS). Its heavy aeration has been sufficient to maintain oxygen levels at the saturation level continuously during experimentation in all parts of the raceway. In addition to the beneficial value of constant, high levels of oxygen to the cultured animals, the aeration also oxidizes the wastes rapidly and prevents the formation of anaerobic conditions throughout the system.

Water circulation is created with this pump system by attaching elbows to the upper end of each airlift. This creates a current in the tanks which can be adjusted by changing the angle of the elbows. The tank design (rectangular with rounded ends and a centre wall) was chosen because of circulation patterns occurring in the tank. Sufficient current velocities are maintained to keep particulate wastes suspended in the water column.

In Texas, winter temperatures are too low for penaeid shrimp, therefore, a closed system is used to avoid unnecessary heat loss. Temperature control is accomplished through shading, solar heating and with a gas-heated heat exchanger during cold weather. Water temperatures have been maintained within a range of about $4^{\circ}C$ when this system was functioning properly.

No chemical control has been used in the system although its size (43 000 l) and the fact that no water is exchanged would enhance evaluation of chemical control techniques.

Labour requirements, which can be measured for any system, are related to the levels of control exercised, the degree of automation, and the design of the model.

The closed system has the advantage of producing no effluent, but it does require elaborate waste treatment to maintain suitable water quality at high stocking levels. For this purpose a variety of physical and biological filters have been tested. Those used in the present model are: an inclined plate separator for removal of particulate wastes; a protein skimmer; and a biodisk filter for removal of dissolved wastes (Mock, MS). One factor considered in the selection of these filters was the ease of recovery of filtered wastes and biological growths, since these can be utilized.

Although this model is still in the developmental stages, the use of the system has helped evaluate various forms of environmental control.

The beneficial effects of several inputs have been surprising: aeration, water circulation and waste removal by filtration. Waste removal by filtration has been difficult to measure and standardize but Ross, Mock and Salser (MS) have obtained preliminary data on the effects of small filters on the chemical nature of filtered water.

4. DISCUSSION

There has been a reluctance among aquaculturists to explore the use of high-density culture systems. Reasons given for the lack of experimentation with intensive, controlled systems are: high initial costs; the projected large energy inputs required; and the level of technology required to operate the systems. None of these is an adequate rationale to discourage the use of intensive models for the purposes already described. In fact, models should be used to study methods of increasing production without excessive capital investment, high energy requirements or complicated technological input.

If aquaculturists are willing to depart from traditional constraints and seriously consider new and more progressive approaches to aquaculture, there are many opportunities to increase control of systems without excessive expenses. For example, techniques for the efficient use of solar energy and wind are being developed rapidly, and these uses may involve relatively low costs. Circulation of water within a pond or tank has many desirable effects, but the uses of wind, tides or water power for this purpose have not been explored thoroughly. The use of aquacultural wastes to produce methane for fuel is another area which seems to offer considerable potential with present technology and relatively low investment costs. Numerous other possibilities exist for the economical application of engineering technology to aquaculture.

If the full potential of the husbandry of aquatic plants and animals is to be realized we must be willing to develop a new technology which will offer means of controlling the organism cultured and its environment. The use of models will aid in this development.

5. REFERENCES

Mahler, L.W., J.E. Groh and C.N. Hodges, Controlled environment aquaculture. Proc.Annu. 1975 Workshop World Maricult.Soc., 5:379-84

Mock, C.R. and R.A. Neal, Engineering aspects of a closed system for aquaculture. Paper 1975 presented at the 10th European Symposium on Marine Biology, Ostend, Belgium, September, 1975 (MS)

Mock, C.R., R.A. Neal and B.R. Salser, A closed raceway for the culture of shrimp. Proc. 1974 Annu.Workshop World Maricult.Soc., 4:247-59

Mock, C.R., L.R. Ross and B.R. Salser, Design and evaluation of waste removal systems for 1975 shrimp culture in closed raceways. Paper presented at the Sixth Annual Workshop of the World Mariculture Society, January, 1975 (MS)

Ross, L.R., C.R. Mock and B.R. Salser, Observations on water quality in closed raceway systems 1975 used for shrimp culture. Paper presented at the Sixth Annual Workshop of the World Mariculture Society, January, 1975 (MS)

Zein-Eldin, Z.P. and J.L. Fenucci, Effect of protein levels and sources on growth of *Penaeus* 1976 *aztecus*. Paper presented at the FAO Technical Conference on Aquaculture, Kyoto, Japan, 26 May-2 June, 1976